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Rage against the Machines: Labor-Saving Technology and Unrest in Industrializing England†

By Bruno Caprettini and Hans-Joachim Voth*

Can new technology cause social instability and unrest? We examine the famous "Captain Swing" riots in 1830s England. Newly collected data on threshing machine diffusion shows that labor-saving technology was associated with more riots. We instrument technology adoption with the share of heavy soils in a parish: IV estimates demonstrate that threshing machines were an important cause of unrest. Where alternative employment opportunities softened the blow of new technology, there was less rioting. Conversely, where enclosures had impoverished workers, the effect of threshing machines on rioting was amplified. (*JEL* J24, L16, N13, N33, N53, O33, Q16)

From the invention of steam engines to the IT revolution, the adoption of new technologies has gone hand in hand with massive job destruction. Spinners and weavers were made redundant by steam-powered textile mills 200 years ago; more recently, computers have replaced phone operators, bookkeepers, and others performing routine jobs, reducing incomes (Autor, Levy, and Murnane 2003). Classical economists from Marx to Leontief and Keynes predicted that technological unemployment would lead to social and political instability (Marx 1867, Keynes 1931, Leontief 1952).

And yet, despite clear evidence that labor-saving technical change puts downward pressure on wages (Acemoglu and Autor 2011), its social and political consequences are largely unexplored. In this paper, we examine whether the introduction of labor-saving technology can cause social instability and political unrest. We do so by looking at the famous "Captain Swing" riots in 1830s England—the largest wave

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of unrest in English history, with more than 3,000 cases of arson, looting, attacks on authorities, and machine breaking across 45 counties.[1]

Bad weather, a poor harvest, and news of the French and Belgian Revolutions contributed to unrest in 1830 (Archer 2000, Charlesworth 1979, Hobsbawm and Rudé 1969). Earlier immiserization had prepared the ground. Enclosures took away rural workers' access to the commons, transforming them into a "landless proletarian, relying almost exclusively on wage-labor" (Hobsbawm and Rudé 1969, p. 35), and Irish immigration put further pressure on incomes (Mokyr, Vickers, and Ziebarth 2015). While England operated an early welfare system (the Poor Laws), it came under increasing strain (Boyer 1990). Enclosures, Poor Laws, and mechanization appear in almost every account of the Swing Riots, but there is so far no hard evidence to establish the importance of individual factors or demonstrate causal effects.

We collect new data on threshing machine diffusion from contemporary newspapers and agricultural surveys. Threshing machines separate the grain from the chaff, replacing hand threshing with a flail swung overhead. We show that labor-saving technology was a key factor behind the Swing Riots. In parishes without threshing machines, the riot probability was 13.6 percent; in places where they had spread, it was twice as high (26.1 percent). Regression results suggest that every extra thresher in a parish sharply increased the frequency of unrest. These OLS results are robust to the inclusion of many controls and the use of different estimation strategies. Technology adoption itself may have been affected by the risk of riots. To identify the causal effect of new technology, we instrument threshing machine adoption with soil composition. We use the share of heavy, clay-rich soils, which predicts wheat cultivation—the only crop that could be processed profitably with early threshing machines. We obtain strong IV results, confirming the link between labor-saving technology adoption and unrest.

Two factors tended to modify riot frequency. Enclosure of common land appears to exacerbate the effect of machines on riots. Workers whose livelihood was threatened by new technology had two choices, "voice" and "exit" (Hirschman 1970)—they could leave or engage in (violent) action. In line with this, parishes close to manufacturing centers saw fewer protests, suggesting that "exit" reduced protest frequency.

I. Historical Background

English agriculture by 1800 was efficient and highly commercialized, with most output sold on the market (Crafts 1985). Large farms operated with hired labor, often employed in threshing during the winter (Thompson 1966). Threshing is a key agricultural activity, loosening the grains from the husks. It is also a laborious process, traditionally using flails swung overhead. Threshing accounted for up to 50 percent of rural laborer's winter income prior to mechanization (Clark 2001).[2]

[1] The riots had lasting consequences, ushering in a period of institutional reform (Aidt and Franck 2015).

[2] The Hammonds cite a landowner from Canterbury as saying that in his parish, "where no machines had been introduced, there were twenty-three barns…in these barns fifteen men at least would find employment threshing corn up till May" (Hammond and Hammond 1920, p. 221).

In 1786, Andrew Meikle invented the first threshing machine (Macdonald 1975). Early threshing machines were expensive and unreliable. They spread slowly (Hobsbawm and Rudé 1969, Macdonald 1975). After 1810, adoption accelerated as prices declined and reliability grew (Hobsbawm and Rudé 1969). Machines operated by horses (water) on average increased productivity per worker by a factor of 5 (10) (online Appendix B.8). Threshing machines increasingly deprived rural laborers of their main source of income during the winter. Where they had spread, winter unemployment was 7.6 percent; in unaffected areas, it stood at 5.5 percent.[3]

The first Swing Riots broke out in August 1830 in Kent (Hobsbawm and Rudé 1969). They quickly spread, with more than 3,000 riots erupting across 45 counties. Figure 1, panel A shows the geography of unrest. Arson was frequent (Tilly 1998). In the second half of 1830 alone, 514 threshing machines were attacked (Holland 2005). All rioters were either rural workers or local craftsmen (Stevenson 1979). Unrest was eventually quelled by army units; a special commission passed 252 death sentences (Hobsbawm and Rudé 1969).

II. Data

We collect new data on the diffusion of threshing machines using two sources. We analyze advertisements from 60 regional newspapers published between January 1800 and July 1830, containing 118,758 issues.[4] We search for the string "threshing machine." This yields 549 ads from 466 parishes. These either announce the sale/lease of a farm with a threshing machine, or they come from manufacturers listing the names and locations of their clients.

We complement this list with information from the *General Views of Agriculture*, a set of surveys organized by the Board of Agriculture. Early editions (before 1800) rarely refer to threshing machines. By 1810, however, each volume devotes an entire chapter to them, discussing technical characteristics and the location of individual threshers. We measure parish-level machine adoption as the sum of all threshers found in newspapers and in the *General Views*. Figure 1, panel B shows their geographical distribution.

For unrest, we also use two sources. Data on the Swing Riots come from the Family and Community Historical Research Society (Holland 2005).[5] The underlying sources are judicial records and newspaper accounts. For the years before 1830, we search for the words "arson" and "machine attack" in all newspapers published between 1750 and 1829 in the British Newspaper Archive. This yields a total of 6,392 articles for "arson" and 15,986 articles for "machine attack." To determine whether an article describes an episode of civil unrest, we read each of the "arson" articles and a 35 percent random sample of the "machine attack" articles. We then geolocate every relevant episode. This produces a set of 610 actual arson incidents and 69 attacks on machines between 1758 and 1829. Typos, text of poor quality, and

[3] We combine data on threshing machine diffusion in 1800–1830 (described in Section II) with information on rural unemployment in 1834 (Checkland and Checkland 1974). Summer unemployment was unaffected by machines ($\beta = -0.001$, $p = 0.868$). Online Appendix Table 4 shows that threshing machines predict bigger increases in winter unemployment relative to summer unemployment.

[4] This is the universe of newspaper articles available in the British Newspaper Archive.

[5] Aidt and Franck (2015) use the same data in their study of the political consequences of Swing Riots.

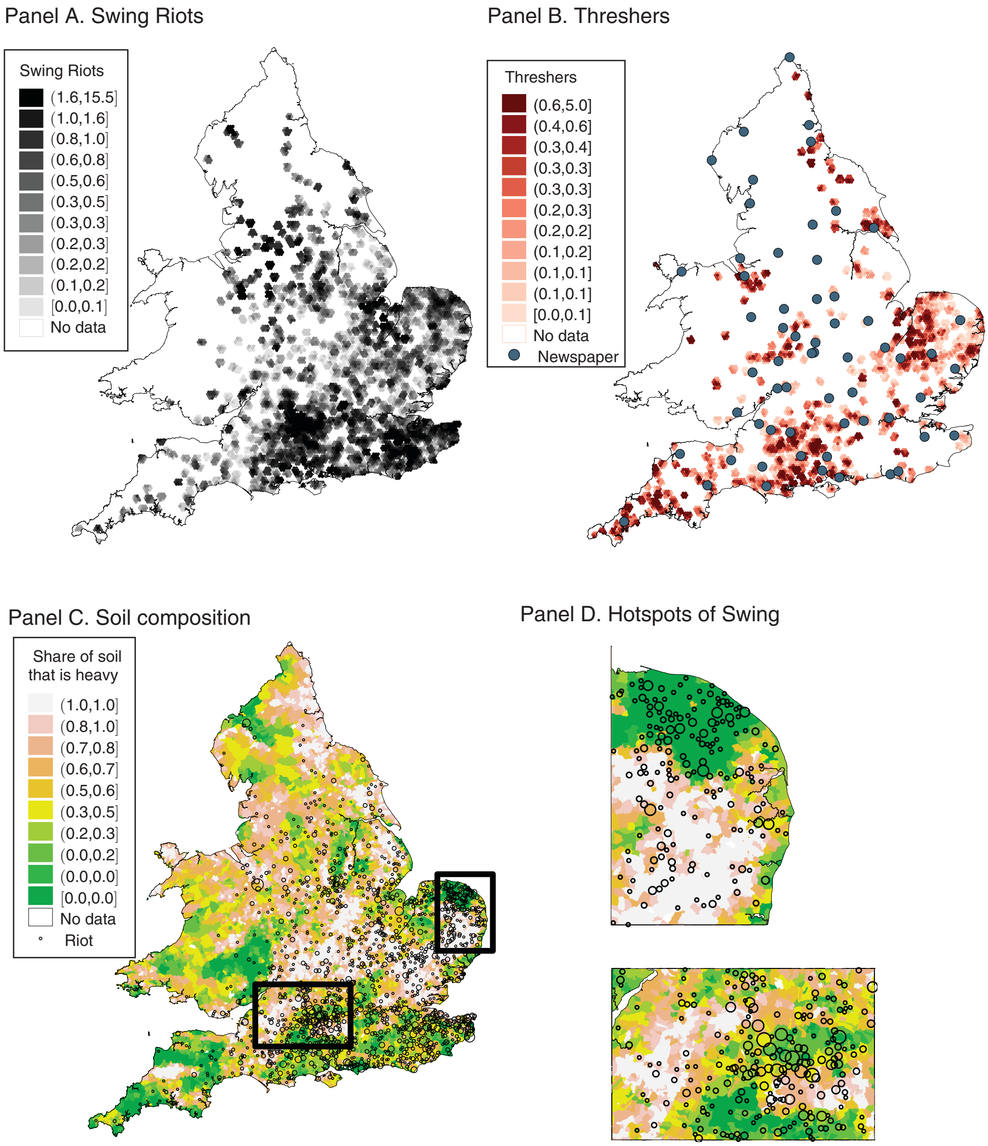

Figure 1. Swing Riots, Threshers, and Soil Composition

Notes: Panel A: distribution of Swing Riots from Holland (2005). We plot a uniform spatial kernel with bandwidth of five kilometers. Panel B: distribution of threshers from British Library and Findmypast (British Newspaper Archive 2016) and *General Views of Agriculture*. We plot a uniform spatial kernel with bandwidth of five kilometers. Panel C: share of parish area that is heavy from Lawley (2009b). Panel D: heavy soils and riots in North Anglia (top) and South England (bottom).

lack of geographical information explain why we can use only a fraction of articles. Moreover, many of the "machine attack" searches returned pages where the words "machine" and "attack" appeared in different articles.[6]

[6]The variable may understate the true number of pre-1830 riots, but we know of no other data that records riots at the level of the parish for these years.

Information on soil composition comes from the 2007 Geological Map of Great Britain (Lawley 2009a, b). For each 1×1 kilometer cell, the map details soil type based on parent soil material.[7] While farming can modify soil composition slowly and at the margin, it is unlikely to have changed the parent soil material between the first half of the 1800s and the twentieth century, the time of measurement. Figure 1, panel C shows the share of heavy soils (rich in clay) in England and Wales. It varies from 0 to 100 percent, often within small geographical units. Each county of the United Kingdom contains a wide variety of soil types.

In addition, we use the British population censuses of 1801–1831 (Southall et al. 2004). For each parish, we construct population density as the log number of people divided by the area, the sex ratio as the log of men over women, and the share of agricultural workers as the number of workers employed in agriculture divided by the total number of workers.

We also calculate distances using parish centroids based on an 1851 map (Southall and Burton 2004). The share of common land enclosed before 1820 is from Gonner (1912). Historical temperature comes from Luterbacher et al. (2004) and historical precipitation from Pauling et al. (2006). We construct abnormal precipitation and temperature in 1830 as the deviation from the average weather in 1800–1828. For general cereal suitability, we use highly geographically disaggregated information on weather patterns and the Food and Agriculture Organization's (FAO) agronomic model ECOCROP. Weather data for this exercise comes from Hijmans et al. (2005), which records temperature and precipitation for the years 1960–1990. Cereal suitability ranges from 1 (high suitability) to 0 (unsuitable).[8] Finally, we use the 1801 corn returns to compute the share of agricultural land that is devoted to wheat cultivation (Turner 1982).

Table 1 reports summary statistics of our variables. We have a maximum of 9,674 units of observation in our data. Unrest is a count variable. In 86 percent of parishes, there were no Swing Riots. Another 11 percent registered one or two incidents. The remaining 3.5 percent saw 3 or more incidents of unrest. The number of threshing machines is similarly skewed, with 94.7 percent of parishes showing no evidence of adoption and another 4.6 percent having only 1. In only 0.75 percent were there 2 or more threshing machines. In an average parish, more than 38 percent of the adult males worked in agriculture, and more than 83 percent of the land was used for cereal cultivation. The spring and summer of 1830 were unusually wet, as indicated by higher-than-average rates of precipitation. Winter unemployment was higher than in the summer by an average of 5.5 percentage points.

[7] Parent soil is the first geological deposit underneath top soils; it determines the characteristics of top soils, including texture, chemistry, and drainage (Lawley 2009a).

[8] Online Appendix A.3 details the construction of the index, and online Appendix A.4 discusses the use of modern weather to estimate 1800 suitability.

Table 1—Summary Statistics

	Min	Mean	Max	SD	Observations
Unrest					
Riots before Swing (1758–1829)	0.000	0.067	32.00	0.687	9,674
Swing Riots (1830–1832)	0.000	0.308	26.00	1.107	9,674
Technology					
Threshing machines (1800–1829)	0.000	0.062	5.000	0.289	9,674
Population					
Density (1801)	0.237	248.5	89,762	2,855	9,674
Share of agricultural workers (1801)	0.000	0.386	1.000	0.265	9,674
Share of trade workers (1801)	0.000	0.117	1.000	0.142	9,674
Share of other workers (1801)	0.000	0.497	1.000	0.273	9,674
Sex ratio (1801)	0.067	0.994	16.35	0.293	9,674
Agriculture					
Share cereal land (1801)	0.000	0.837	1.000	0.119	3,859
Wheat oat value sold ratio (1820s)	0.081	71.74	4,864	370.4	9,562
Wheat oat quantity sold ratio (1820s)	0.025	24.81	2,085	129.9	9,562
Geography					
Distance to Elham (first riot - km)	3.418	237.1	555.7	108.2	9,674
Distance to closest town with newspaper (km)	0.143	24.22	123.7	17.79	9,674
Distance to closest industrial town (km)	0.000	88.54	376.1	63.35	9,674
Share of heavy soil	0.000	0.517	1.000	0.364	9,674
Weather					
Cereal suitability index	0.211	0.634	0.908	0.097	9,674
Abnormal precipitation (spring 1830 - mm)	−0.234	18.76	104.3	15.76	9,674
Abnormal precipitation (summer 1830 - mm)	78.92	104.1	226.0	22.66	9,674
Abnormal temperature (fall 1830 - degrees)	0.126	0.277	0.473	0.068	9,674
Other					
Share of land enclosed (1820)	0.000	2.723	28.46	4.055	6,715
Poor Rates per capita (1803)	0.016	0.695	5.000	0.422	1,251
Unemployment share (winter 1834)	0.000	0.128	1.000	0.151	595
Unemployment share (summer 1834)	0.000	0.067	0.935	0.112	613
Unemployment share (winter–summer 1834)	−0.222	0.055	0.934	0.101	574

Notes: The unit of observation is the parish. Swing Riots are from Holland (2005), and pre-1830 riots are arsons and attacks on machines found in British Library and Findmypast (British Newspaper Archive 2016). Threshing machine adoption is based on our own data collection, using information from the British Library and Findmypast (British Newspaper Archive 2016) and the *General Views of Agriculture*. Population data and sectoral shares come from the decennial censuses of England (Southall et al. 2004). Cultivation patterns are derived from the 1801 crop returns (Turner 1982), and sales ratios for crops come from Brunt and Cannon (2013). Cereal suitability is land suitability for all cereals (rye, oat, barley, wheat) based on the FAO's ECOCROP model. The share of heavy soil in a parish is the surface area classified as "heavy" in the *British Geological Survey Soil Parent Material Model*. Weather data is based on historical precipitation and temperature data in Pauling et al. (2006) and Luterbacher et al. (2004); we calculate abnormal weather conditions by subtracting 1830 weather to average conditions in 1800–1828. Poor Rates per capita is poor relief in pounds per head, based on 1803 spending (taken from the 1832 Royal Commission on the Operation of the Poor Law), divided by 1801 population (from the same source). Further details on variable construction are described in online Appendix A.2.

III. Empirical Analysis

A. *Threshing Machines and Riots*

To examine the association between threshing machines and riots, we estimate variants of

$$Riots_p = \beta_0 + \beta_1 Machines_p + \beta_2 density_{p1801} + \beta_X X_p + \theta_r + e_p, \tag{1}$$

Table 2—Main Results

	Number of Swing Riots		Number of threshers		Number of Swing Riots			
	OLS (1)	OLS (2)	FS (3)	FS (4)	RF (5)	RF (6)	2SLS (7)	2SLS (8)
Threshers	0.389	0.353					6.361	6.557
	[0.071]	[0.071]					[1.616]	[1.768]
Share of heavy soil			−0.034	−0.033	−0.218	−0.214		
			[0.008]	[0.008]	[0.026]	[0.027]		
Cereal suitability index			0.050	0.044	0.130	0.290	−0.186	0.001
			[0.032]	[0.032]	[0.092]	[0.096]	[0.242]	[0.245]
log 1801 density	0.101	0.099	0.015	0.013	0.103	0.100	0.010	0.013
	[0.018]	[0.018]	[0.004]	[0.004]	[0.018]	[0.018]	[0.034]	[0.034]
Share of agricultural workers in 1801	−0.065	−0.056	−0.015	−0.022	−0.073	−0.064	0.024	0.081
	[0.044]	[0.043]	[0.010]	[0.010]	[0.045]	[0.044]	[0.079]	[0.087]
log 1801 sex ratio	−0.181	−0.193	−0.024	−0.011	−0.187	−0.204	−0.035	−0.130
	[0.042]	[0.043]	[0.014]	[0.014]	[0.043]	[0.044]	[0.101]	[0.099]
log distance to Elham	−0.325	−0.217	−0.006	0.070	−0.335	−0.217	−0.294	−0.674
	[0.029]	[0.045]	[0.004]	[0.007]	[0.031]	[0.047]	[0.040]	[0.133]
log distance to newspaper	0.022	0.019	−0.000	0.000	0.022	0.022	0.025	0.022
	[0.018]	[0.019]	[0.005]	[0.006]	[0.018]	[0.019]	[0.036]	[0.041]
Region fixed effects (5)	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.057	0.064	0.006	0.032	0.052	0.061		
Mean dependent variable	0.308	0.308	0.062	0.062	0.308	0.308	0.308	0.308
F-test excluded instrument			17.7	15.9				
Rubin-Anderson test (p)							0.000	0.000
Observations	9,674	9,674	9,674	9,674	9,674	9,674	9,674	9,674

Notes: Columns 1–2: OLS estimates of equation (1); dependent variable is number of Swing Riots. Columns 3–4: first stage estimates of equation (3); dependent variable is number of threshers. Columns 5–6: reduced form estimates of equation (4); dependent variable is number of Swing Riots. Columns 7–8: IV estimates of equation (1), using share of heavy soil as instrument; dependent variable is number of Swing Riots. See online Appendix Table 14 for results with county fixed effects. Robust standard errors in brackets.

where $Riots_p$ is the number of unrest events in parish p during 1830–1832, $Machines_p$ is the number of threshing machines in 1800–1830, $density_{p1801}$ is the (log of) population density from the 1801 Census, and X is a vector of additional controls including share of agricultural workers, male-female ratio (both from the 1801 Census), and distance to the closest newspaper town and to Elham, the village of the first riots. In the most demanding specification, we include θ_r, fixed effects for four regions of England plus Wales.[9]

Table 2 presents our main results. There is a strong, positive correlation between riots and adoption of the new machines. Coefficients are highly significant whether we control for all parish characteristics (column 1) or add region fixed effects (column 2). Controls partly account for alternative explanations. Denser places had more riots; sheer numbers were important to organize collective action. Parishes with higher male-female ratios in 1801 sent fewer men to fight the Napoleonic Wars; these areas experience lower unrest in 1830, suggesting that returning soldiers had a role (Griffin 2012). Finally, contagion was important, as places closer to the first riot in Elham saw significantly more unrest (Aidt, Leon, and Satchell 2017). We lack sufficient data to control for other proposed explanations of the riots, including

[9] Caird (1852) defines these regions based on the similarity of agricultural cultivation.

discontent with the Poor Laws and Irish immigration. We deal with threats to identification in Section IIIB.[10]

The strength of the association is noteworthy because our measure of technology adoption is noisy, biasing our estimates downward (Deaton 1997). Unobservables are unlikely to drive our results—adding controls barely changes the size of the coefficient on threshing machines. If we compare the model on column 2 with the model that only controls for density, we find that selection of unobservables should be 54.8 percent of the selection on observables to rule out a significant effect of machines on riots (Altonji, Elder, and Taber 2005; Oster 2019). This ratio is high, especially because unobservables include all threshing machines in operation in 1830 but not mentioned in newspapers or surveys.

B. *Identification*

There are three reasons why OLS estimates may be biased. First, landlords and farmers may have been less inclined to adopt labor-saving technologies where the risk of protest was high. Anecdotal evidence from the period suggests that this is a valid concern.[11] This would bias estimates downward. Second, there may be omitted variables that affect both the adoption of labor-saving technologies and the likelihood of rural protest. While the inclusion of observed characteristics does not affect point estimates in Table 2, other unobserved characteristics may correlate with technology adoption and riots. This could also affect our estimates. Third, measurement error in technology adoption is likely to bias coefficients downward, because we do not observe all threshing machines in use between 1800 and 1830.[12]

To address these issues we need exogenous variation in the adoption of threshing machines. Suitability to cereal farming in general (any one of wheat, oats, barley, and rye) itself is not plausibly excludable, since it correlates with the number of agricultural laborers in a parish—and without numerous dissatisfied individuals, there could be no riots. Our instrument for thresher adoption is soil suitability *for wheat*. We expect it to predict thresher adoption because wheat was the only grain suitable for mechanical threshing.[13] We measure wheat suitability with the share of land in a parish classified as consisting of "heavy soil," that is, soil rich in clay. Due to the—somewhat unusual—characteristics of clay soils in Britain, the heavier the soil, the harder it was to cultivate wheat:

> Clay…is fertile in proportion to the humus which it contains … It then forms … rich wheat soils which produce many successive abundant crops … The clay soils of Britain are not in general of this fertile kind. They are of a compact nature which retains water … This has made lighter soils, which are more easily worked, to be generally preferred … and the

[10] The number of Swing Riots is a count variable, and almost 86 percent of the parishes do not experience unrest during 1830–1832. Thus, a linear model may not be appropriate. Online Appendix Table 12 shows that results are robust to alternative estimation methods.

[11] For instance Caird (1852, p.18) mentions an Oxfordshire farmer who, instead of using the plough, "had so many hands thrown upon him, that he resorted to spade husbandry, being the best means in which they could be employed."

[12] To illustrate the severity of measurement error, consider that we observe direct attacks on threshers in 320 parishes. Only 36 of them (11 percent) had published advertisements mentioning these machines.

[13] Hobsbawm and Rudé (1969) argue that "oats and barley were definitely cheaper to thresh by hand."

> mode of cultivation of the light soils has advanced more rapidly towards perfection than that of the clays.
>
> (Rahm 1844, p.146, entry on "clay")

In other words, since wheat was the most valuable cash crop grown by farmers, it was more often sown on the lighter soils.[14]

C. *Validity of the Instrument: Balance, Pretrends, and First Stage*

Figure 2, panel A documents the strength of the unconditional association between soil composition and threshing machine adoption. It shows a binscatter of threshers (on the *y*-axis) against the share of heavy soils (*x*-axis). As the share of heavy soil increases from 0 percent to 100 percent, the penetration of threshing machines falls by half.

Figure 2, panel B shows that the share of heavy soils in a parish is not correlated with welfare support (Poor Rates per capita), distance to Elham (where the first riots erupted), occupational composition, population density, the sex ratio, or the share of cereals grown. Crucially, our data is also balanced in terms of pre-1830 unrest.

Panel C shows the effect of heavy soil on unrest over time. We estimate the following panel regression:

$$(2)\quad Riots_{pt} = \gamma_p + \sum_{t=pre1800}^{1830} \gamma_{1t} \cdot Share\ heavy_p + \gamma_2 density_{pt} + \gamma_X X_{pt} + \chi_{rt} + v_{pt},$$

where t indicates time-varying variables, and the unit of observation is a parish-decade. We control for parish fixed effects and decade fixed effects interacted with regional dummies, the share of heavy soil, and distances. Figure 2, panel C plots the coefficients and 95 percent confidence intervals of the share of heavy soils interacted with decade dummies. The effect of heavy soil on pre-1830 unrest is small and insignificant before 1830 and then becomes large and significant. This suggests that before threshing machines spread, soil characteristics promoting wheat farming were not associated with more civic unrest.

Next, we regress the number of threshing machines in parish p ($Machines_p$) on the share of heavy soil in a parish:

$$(3)\quad Machines_p = \alpha_0 + \alpha_1 Share\ heavy_p + \alpha_2 density_{p1801} + \alpha_X X_p + \psi_r + u_p.$$

The first stage is strong in all specifications (Table 2, columns 3–4). The F-statistic is 17.7 with controls and 15.9 when adding region fixed effects.

D. *Reduced Form and IV Results*

Before presenting reduced form and IV results, we illustrate our findings. Figure 1 combines information on soil composition, threshing machine adoption, and the location of Swing Riots. Panel A gives the distribution of riots. Panel

[14] Online Appendix Table 7 shows that land usage correlates with soil suitability. It uses information on value and quantity of different crops sold in various market towns of England. In terms of the value of crops sold, wheat lost out to oats where the soil is heavy (columns 1–4). The same is true for quantities (columns 5–8).

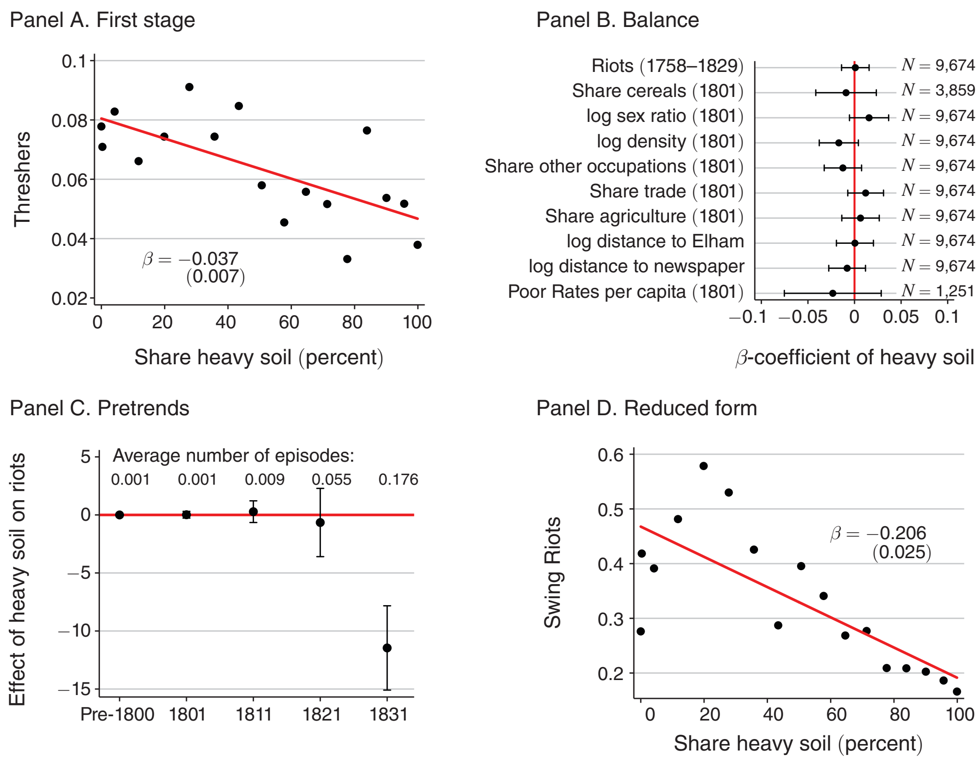

FIGURE 2. VALIDITY OF THE IV: FIRST STAGE, BALANCE, PRETRENDS, AND REDUCED FORM

Notes: Panel A: first stage. Unconditional binscatter of the share of heavy soils (x-axis) against number of threshers (y-axis). From the full sample of 9,674 parishes, we create 20 bins of roughly equal sample size; the first 2 and last 3 bins have no variation in share of heavy soils and are combined into a single data point. Slope estimated from a bivariate regression of number of threshers on share of heavy soils in the full sample; robust standard errors in parentheses. Panel B: graph plots standardized beta coefficients of bivariate regressions of the variables listed on the left on the share of heavy soil, showing balance in our sample. Bars represent 95 percent confidence intervals calculated from robust standard errors. See online Appendix Table 8, column 1 for nonstandardized coefficients. Panel C: relationship between pre-1830 riots and share of heavy soils. The graph plots the estimates and 95 percent confidence intervals of γ_{1t} from equation (2) in the text. We report the average number of episodes in every decade on top of the estimates. See online Appendix Table 9, column 4 for full estimates. Panel D: reduced form. Unconditional binscatter of the share of heavy soil (x-axis) against number of Swing Riots (y-axis). From the full sample of 9,674 parishes, we create 20 bins of roughly equal sample size; the first 2 and last 3 bins have no variation in share of heavy soils and are combined into a single data point. Slope estimated from a bivariate regression of the number of Swing Riots on share of heavy soils in the full sample; robust standard errors in parentheses.

B shows the spread of threshers by 1830 and panel C the distribution of heavy soils. Riots were concentrated in Wiltshire, Berkshire, and Hampshire, in the southeastern counties of Kent and Sussex, and in Norfolk. These regions are also the ones that are more suitable to wheat cultivation, as indicated by their lower share of heavy soils. Where threshers spread the most, unrest erupted frequently in 1830.

The reduced form results point to a strong and robust relationship between our instrument and the incidence of riots. Figure 2, panel D shows an unconditional binscatter of threshers (on the y-axis) against the share of heavy soils (x-axis). As the share of heavy soil increases from 0 to 100 percent, the likelihood of riots falls from over 40 to less than 20 percent. In Table 2, columns 5–6, we add controls and estimate:

$$(4) \qquad Riots_p = \gamma_0 + \gamma_1 Share\ heavy_p + \gamma_2 density_{p1801} + \gamma_X X_p + \chi_r + v_p,$$

where variables are defined as in equations (1) and (3). When controlling for other factors, a higher share of heavy soil in a parish strongly predicts fewer riots.

The IV results similarly show a strong link between threshing and unrest. Whether we use region fixed effects or not, we find that there is a large and significant effect from the part of machine adoption determined by soil composition on riot incidence. The IV estimates in Table 2 suggest that one extra machine, installed because of land characteristics, translated into 6.4–6.6 more riots during 1830–1832. These numbers are significantly larger than OLS estimates for the reasons we discussed in Section IIIB.

Our OLS, reduced form, and IV results are robust to a wide range of alternative estimation methods, the inclusion of county fixed effects, and different corrections for spatial autocorrelation as well as estimation for areas close to towns with newspapers (online Appendix C).

IV. Aggravating and Mitigating Circumstances

What factors amplified or mitigated the impact of technology adoption on unrest? We document that in areas where other factors impoverished rural workers, the relationship between technology adoption and riots was stronger. In contrast, access to alternative employment dampened the effect of mechanization on riots. For this analysis, we study the relationship between machines and riots in different sample splits. Because the first stage loses power in subsamples, we use simple OLS, viewing the results in this section as suggestive.[15]

A. *Alternative Employment*

Where workers could easily find alternative employment, labor-saving technologies did not lead to social unrest—workers chose "exit" and not "voice" in the parlance of Hirschman (1970). In 1830s England, many towns were thriving. We expect rural workers living in areas nearby to migrate more readily in response to the introduction of labor-saving machines. In other words, in the presence of alternative urban employment opportunities, the introduction of threshing machines should engender less opposition, resulting in fewer Swing Riots.

For each parish in England, we compute the distance to the closest manufacturing center. We split the sample into above-median and below-median distance from one

[15] With region fixed effects, the F-statistic drops to 2.3 in the subsample of parishes close to industrial towns. It drops to 2.6 in the subsample of parishes with much enclosed land. With weak instruments IV estimates have non-normal distributions, and standard inference is invalid (Stock, Wright, and Yogo 2002).

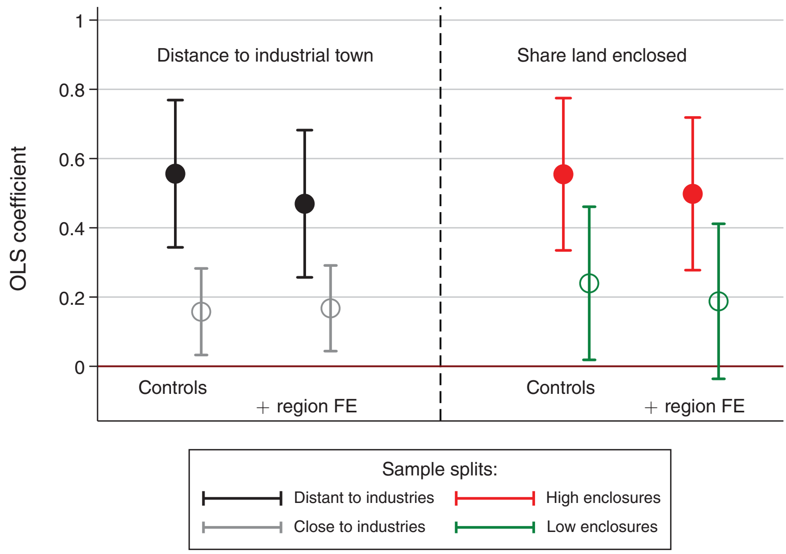

Figure 3. Aggravating and Attenuating Circumstances

Notes: The figure reports point estimates and 95 percent confidence intervals for equation (1) estimated on different sample splits. We estimate simple OLS regression as the first stage loses power in subsamples. Left panel: parishes distant from (close to) industries are above (below) the median distance from one of the 15 manufacturing centers of England (see online Appendix A.2 for details). See online Appendix Table 10 for full results. Right panel: parishes with high (low) enclosures are above (below) the median level of enclosure (see online Appendix A.2 for details). See online Appendix Table 11 for full results.

of these 15 centers. The half that is closest to a manufacturing city will arguably have greater scope for rural-urban migration.[16]

We plot OLS estimates of equation (1) for the two subsamples in the left panel of Figure 3 (full results are in online Appendix Table 10). Solid black dots show that adoption of threshing machines was associated with significantly more riots in the 4,785 parishes that lie far away from manufacturing centers. The relationship is still significantly different from 0 for the other, closer half of the sample, but the coefficient is only one-third in size. The coefficients are significantly different from each other in all specifications.

B. *Enclosures*

We now ask whether enclosure prior to 1820 amplified the effect of machine adoption on riots. This is plausible because enclosure on average worsened conditions for agricultural laborers, who had often kept cows or sheep on the commons (Neeson 1996, Mingay 2014). Where most land is enclosed, labor-saving technologies are especially harmful to workers since they have no other source of income.

[16] The 15 manufacturing centers are in Cheshire, Lancashire, Middlesex, Norfolk, Warwickshire, and Yorkshire, West Riding. See Online Appendix A.2 for details. The median parish is Waterstock in Oxfordshire, which lies 74 kilometers from Blackburn.

In the right panel of Figure 3, we split our sample into two groups by proportion of land enclosed (full results are in online Appendix Table 11).[17] The figure shows OLS regressions, with solid red dots for above-median enclosures and open green ones for below-median parishes. In all cases, the relationship between machines and riots is strong and precisely estimated in parishes with above-median enclosures. In contrast, we find a markedly smaller effect in areas with few enclosures.

V. Conclusions

During one famous historical episode, the Swing Riots in Britain in 1830–1832, unrest was strongly correlated with the adoption of labor-saving technology. Using newly collected data on the diffusion of threshing machines, we demonstrate that where threshing machines had spread, the probability of riots was twice as high as in areas where they had not been adopted. We use soil suitability for wheat to identify an exogenous cause of threshing machine adoption—the machines were unsuitable for other crops. Areas with better conditions for wheat cultivation witnessed both greater adoption of threshing machines and markedly more riots. Importantly, soil suitability for wheat is uncorrelated with grain suitability overall. Areas most suited for wheat—and hence the adoption of threshing machines—also had not witnessed more social unrest prior to 1830, reducing the risk of pretrends and unobservable factors driving our results. While many factors led to the outbreak of unrest in England and Wales in 1830–1832, we demonstrate a clear causal contribution of technological change to social unrest.

New technology did not spell more unrest everywhere. In areas far from major manufacturing towns, we find tentative evidence that threshing machine adoption had stronger effects on arson, attacks on the local authorities, machine breaking, or tumultuous assemblies. In contrast, where ease of access to alternative employment made workers' exit a realistic option, technological unemployment was less likely to translate into social unrest. The same pattern is visible under OLS for enclosures. Where workers had lost access to common lands, reducing their income, threshing machine adoption tended to spell more political instability.

Our findings unify the literatures on technological change and the economic determinants of unrest, providing evidence for an additional channel—the distributional effect of the new technology. The current literature on income and unrest overwhelmingly focuses on negative shocks. In contrast, new technologies represent a positive shock to output and productivity. Threshing machines are labor saving, producing the same output with less work. This increased profits for landowners but reduced the share of income going to labor.[18] Second, we focus on a large and rapid dislocation in the labor market driven by technological change. Threshing was the main income source for agricultural laborers for many months of the year. Mechanical threshing

[17] We only observe enclosures for registration districts, and parishes in the same district share the same value of enclosure. The median parish is in the districts of Biggleswade (Bedford), Billericay, Colchester, Ongar, and Romford (Essex), and Market Harborough (Leicester). There are 107 parishes in these districts, and we assign them to the "low" enclosure group; this is the reason why splitting parishes at the median does not produce two samples of exactly the same size.

[18] The importance of distributional effects of income shocks is central to the theory of Dal Bó and Dal Bó (2011). Dube and Vargas (2013) show evidence consistent with this theory looking at civil war in Colombia.

largely eliminated winter earnings for agricultural laborers, who constituted the relative majority of the labor force in most English counties (Shaw-Taylor et al. 2010). This is in contrast with more recent cases of technological change, which involve relatively gradual shifts affecting a small part of the labor force (such as telephone operators or secretaries). Third, while threshing machines substituted unskilled workers, they did not create new occupations for skilled ones: manual threshers were replaced with equipment operated by horses, women, and boys. This is in contrast with more recent cases of technology adoption, which often increase demand for high-skill jobs (Autor, Katz, Krueger 1998; Acemoglu and Restrepo 2020).

Social unrest as a result of technological unemployment has so far been a rare event—but such tranquility is not inevitable. The Swing Riots demonstrate that rapid, regionally concentrated job losses can quickly lead to political instability and violence.

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